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PARASITOLOGY

Epidemiology and economic impact of bovine cysticercosis in the state of Espírito Santo, Brazil

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ABSTRACT: *Bovine cysticercosis (BCC) is an important disease in Brazil due to its detection in abattoirs, resulting in economic losses for cattle farmers, and a public health corcern. Besides its importance, the knowledge about BCC epidemiology and impact remains not fully described in several areas in this country, requiring more studies. Thus, this study focused on establishing BCC prevalence in the regions and municipalities of the state of Espírito Santo from 2017 to 2019, establishing the associated risk factors, and estimating the economic losses for cattle farmers. A set of 2,330 cases of BCC was detected in the 407,529 bovine inspected by Federal Inspection Service (0.57%; C.I. 95% 0.55 – 0.60%) with a higher detection of unviable cysticercus (66.14%). The beef producers lost at least US$153,000.20 due to BCC through this period. The highest risk for BCC infection occurred in Metropolitana (OR = 9.19), Litoral Sul (OR = 7.77), Caparó (OR = 7.44), and Central Sul (OR = 7.19) mesoregions, respectively. The BCC was detected in animals from 67 municipalities and its prevalence increased in areas with high human population density (OR = 1.58;; p = 0.01). In conclusion, BCC is an important disease for beef production chain in the Brazilian state of Espírito Santo and a cause of economic losses, mainly in some areas, and urgently requires the adoption of prophylactic strategies to reduce the ocurrence of this parasite.*
Key words: *beef, meat inspection, parasitology, Taenia saginata.*

Epidemiologia e impacto econômico da cisticercose bovina no Estado do Espírito Santo, Brasil

RESUMO: *A cisticercose bovina (CB) é uma doença importante no Brasil devido à sua detecção em abatedouros-frigoríficos que resulta em impactos econômicos aos criadores de bovinos, e um problema de saúde pública. Apesar da sua importância, o conhecimento sobre a sua epidemiologia e impacto persiste não completamente descritos em diversas áreas do país requer mais estudos. Portanto, esse estudo objetivou estabelecer a prevalência nos municípios e regiões do Estado do Espírito Santo de 2017 a 2019; estabelecer os fatores de risco associados; e estimar o impacto econômico aos pecuaristas. Durante o período, 2.330 casos de BC foram dectados entre os 407.529 bovinos inspecionados sob regime de inspeção federal (0,57%; I.C. 95% 0,55 – 0,60%), com maior frequência de cisticercos inviáveis (66,14%). Os pecuaristas perderam pelo menos US$153.000,20 devido à ocorrência de CB durante o período. As áreas de maior risco para a enfermidade nesse estado estão nas mesoregiões Metropolitana (OR = 9,19), Litoral Sul (OR = 7,77), Caparó (OR = 7,44), e Central Sul (OR = 7,19), respectivamente. A doença foi detectada em animais de 67 municípios e a prevalência da enfermidade foi maior em áreas com elevada densidade populacional humana (OR = 1,58; p = 0,01). Assim, conclui-se que a CB é uma importante doença para a cadeia da carne bovina no estado, além de uma importante causa de perdas econômicas, principalmente em algumas áreas, e necessita, urgentemente, da adoação de medidas profiláticas para reduzir a ocorrência desse parasita.*
Palavras-chave: *carne, inspeção de carnes, parasitologia, Taenia saginata.*

INTRODUCTION

Taenia saginata is a parasite that infects the small intestine of humans (definitive hosts) and its larval stage occurs on viscera and muscles of cattle (intermediate hosts). Humans acquire taeniasis upon ingestion of raw or undercooked beef containing viable cysticerci while cattle get infected through the ingestion of food and water contaminated with eggs, which will hatch, leading to oncospheres settling in tissues of

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bovine and further developing into cysticerci. The infection in both species is frequently asymptomatic but mild gastrointestinal symptoms are described in taeniasis cases. Rarely the infections are severe; however, even stomach-perforation and parasite regurgitation was reported (DBOUK et al., 2021).

Conversely, bovine cysticercosis (BCC), besides asymptomatic infections, is important for beef producers due to the economical losses originated from the condemnation or treatment (heating, freezing, or salting) of infected carcasses and viscera after *post mortem* inspection in abattoirs (HENCKEL et al., 2020). According to COMIN et al. (2021), farmers located in the Brazilian state of São Paulo lost at least US$ 5,829,103.99 due to BCC detection from 2017 to 2019.

In Brazil, a country that has an 8,516,000 km² area and is the most important beef exporter, BCC is endemic and its spatial distribution varies in regions, states, cities, and farms. Besides the large amount of spatial data available in this country (COMIN et al., 2021; HENCKEL et al., 2020; ALVES et al., 2017; AQUINO et al., 2017; PEREIRA et al., 2017; ROSSI et al., 2017; ROSSI et al., 2016; AVELAR et al., 2016; FERREIRA et al. 2014; GUIMARÃES-PEIXOTO et al. 2012), the knowledge about BCC epidemiology and impact remains not fully described (ROSSI et al., 2020). The knowledge about the main BCC-affected areas allows establishing priority for the adoption of prophylactic strategies by human and animal health agencies. The prevention and control of BCC are possible, mainly where Good Agricultural Practices (GAP) are adopted during animal raising, and it is possible to reduce the exposure to risk factors, such as the cattle's access to uncontrolled water sources (ROSSI et al., 2015).

Taking into account the need for more research in Brazilian areas, this study focused on establishing BCC prevalence in the regions and municipalities of the Espírito Santo state from 2017 to 2019, associating the risk factors and estimating the economical losses for beef producers in this area.

MATERIALS AND METHODS

Study area and data collection

The studied region was the state of Espírito Santo, located in the Southeast region of Brazil. This state is composed of 78 municipalities that are distributed in ten regions (Figure 1). Data of *post mortem* inspected cattle (407,529 animals) and cysticerci (viable and unviable) detection in animals originating from 75 municipalities, during the period from January 1st, 2017 until December 31st, 2019, was gathered from a federal government database (SIGSIF/MAPA; http://www.agricultura.gov.br/assuntos/inspecao/produtos-animal/sif) (BRAZIL, 2021). This study included only the inspection at abattoirs under Federal Inspection Service. The number of infected carcasses containing viable and/or unviable BCC in slaughtered cattle was gathered for each municipality. We used data from 75 municipalities in this study. Three municipalities (Irupi, Marechal Floriano, and Vitória) were not included due to the absence of data in the consulted database, probably because the cattle raised in such regions were not slaughtered under the supervision of federal sanitary inspection service.

The *post-mortem* inspection for BCC was performed according to Brazilian legislation through visualization, palpation, and incisions on several sites of the carcasses and viscera. These sites include head (incisions in masseter or pterygoid muscles), tongue (palpation and a unique longitudinal incision), liver (visual inspection including bile ducts), heart (multiple incisions with atria and ventricles exposed), diaphragm (palpation and incisions), and esophagus (palpation and incisions). If BCC is detected in an inspection line, the carcass and viscera are sent to the Final Inspection Department (DIF), where the esophagus and liver are visually revised and other incisions are performed in the head, tongue, heart, diaphragm, and carcass muscles (BRAZIL, 1971). The cysticerci were visually classified into viables or unviables, and those carcasses containing both were considered as infected with viable ones.

In addition, data regarding characteristics of these 75 municipalities which could be related to BCC frequency, which were available in the Brazilian Institute of Geography and Statistics (IBGE) database (https://cidades.ibge.gov.br/), were collected, such as estimated human population size, demographic density, Human Development Index (HDI), children mortality rate, number of houses with sewage system (%), cattle herd size, and poverty index (%).

Data analysis

Prevalence values were determined for each municipality using individual cattle as the epidemiological unit, while risk factors were assessed with the municipality as the epidemiological unit. BCC prevalence was calculated for state, mesoregion, and municipality levels dividing the number of infected carcasses by the total amount of slaughtered cattle. The 95% confidence intervals (CI) of BCC prevalence values were calculated using Wilson's method, through the binomial R package. The higher risk administrative regions were established comparing them with the

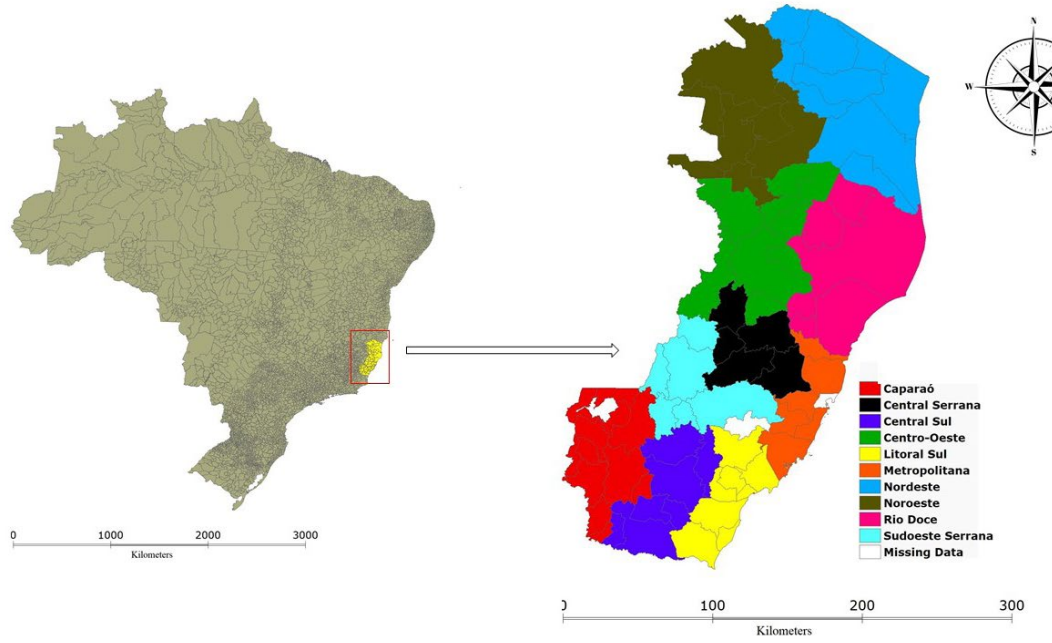

Figure 1 - Spatial distribution of the 75 municipalities located in the state of Espírito Santo, Brazil, in the ten regions (Caparaó, Central Serrana, Central Sul, Centro-Oeste, Litoral Sul, Metropolitana, Nordeste, Noroeste, Rio Doce, and Sudoeste Serrana).

one with the lowest prevalence (OR = 1) and the chi-square test (THRUSFIELD & CRHISTLEY, 2018).

In order to perform ordinal logistic regression, BCC prevalence, estimated human population size, demographic density, Human Development Index (HDI), children mortality rate, number of houses with sewage system (%), cattle herd size, and poverty index (%) were categorized using the quartiles. Initially, the putative variables were investigated one by one using Fisher exact test, and those that presented $p > 0.20$ were removed. After this, the non-removed variables were analyzed using simple ordinal logistic regression analysis, one by one, using the "polr" function from the "MASS" package of the R software. Epidemiological analyses were performed using both Epiinfo 7® and SAEG 9.0 softwares, and maps were created using the Terraview® Software (INPE, Brazil) (SOFTWARE TERRAVIEW®, 2020) considering the corresponding quartiles.

Financial loss estimation

The Brazilian law (Decree 9.013 published at 29 March 2017) states that carcasses with a single unviable cysticercus must have it removed and are liberated (human consumption without treatment). Those carcasses with a single viable cysticercus must be submitted to freezing at -10 ºC for at least ten days or salt treatment for 21 days in specific conditions. In addition, carcasses are only condemned for human consumption if there is an intense infection, which is characterized by the presence of at least eight cysticerci distributed as follow: at least two cysticerci in at least two preferential sites (masseter or pterygoid muscles, tongue, heart, diaphragm, esophagus, and liver), totalizing four cysticerci, and at least four or more cysticerci in forequarter and hindquarters cuts (chuck, brisket, shank, round, and sirloin). The carcasses presenting more than one cysticercus but less intense infections must be heat-treated (76.6 ºC for at least 30 minutes or canning) (BRAZIL, 2017).

The financial losses due to BCC for cattle farmers were evaluated using the penalties system frequently used in Brazilian abattoirs according to this classification of infection intensity established by the Brazilian law in the Decree N° 9,013/2017 (BRAZIL, 2017). These criteria were used for

the calculation of economic losses for beef farmers considering the percentage of destinations and the monetary discount applied by slaughterhouses. For this purpose, the average carcass value was considered as US$463.09, the discount when carcasses were destinated to freezing or salt treatment as a 20% reduction on price (-US$ 92.61 per animal) and 100% (-US$ 463.09 per animal) when destinated to heat treatment or rendering. Those carcasses with only one unviable cysticercus did not cause a reduction in the monetary values for cattle farmers and; consequently, no losses were considered in the calculations. The percentage of carcasses destination, which is unavailable in the Brazilian Ministry database, was considered as equal to HENCKEL et al. (2020).

RESULTS

A set of 2,330 BCC cases was detected from the 407,529 bovines inspected, resulting on a prevalence of 0.57% (C.I. 95% 0.55 – 0.60%) (Table 1). The viable cysticercus were less frequently detected (33.86%) compared to the unviable ones (66.14%). The beef producers lost at least US$153,000.20 due to BCC detection in abattoirs (Table 2).

Regarding the ten regions, the lowest prevalence was observed in Nordeste (0.22%; C.I. 95% 0.20-0.25%) while the highest one was in Metropolitana (2.00%; C.I. 95% 1.79 – 2.23%). The highest *odds ratio* for BCC infection occurred respectively in Metropolitana, Litoral Sul Caparaó and Central Sul (Table 1). BCC was present and absent on animals from 67 and eight municipalities, respectively. The highest BCC prevalence was detected in the following municipalities: Anchieta (6.70%; C.I. 95% 5.09 – 8.78%), Jerônimo Monteiro (4.73%; 3.59 – 6.21%), Vila Velha (3.90%; 2.61 – 5.78%), Ibitirama (3.45%; 1.98 - 5.93%), Dores do Rio Preto (2.96%; 1.66 – 5.22%), Viana (2.59%; 2.22 – 3.03%), Iconha (2.55%; 1.39 – 4.63%), Ibatiba (2.47%; 0.68 – 8.56%), Divino de São Lourenço (2.21%; 1.01 – 4.73%), Mimoso do Sul (2.21%; 1.89 – 2.58%), Cariacica (2.20%; 1.65 – 2.93%), and Vargem Alta (2.00%; 0.35 – 10.50%). The spatial distribution of BCC prevalence (viable, unviable, and total) in the 75 municipalities is shown in figure 2.

Regarding the putative variables for the increase in the risk of BCC, using Fisher exact test, the cattle population size (P = 0.19) and human density (P = 0.10) were considered for ordinal logistic regression. In this step, only the variable higher human density contributed for a significant higher risk for BCC (OR = 1.58; C.I. 95% 1.08 – 2.32; p = 0.01).

DISCUSSION

BCC is not a problem restricted to Brazil and its epidemiology has been well described in several large systematic reviews and/or meta-analysis including other continents – such as Europe (LARANJO-GONZÁLEZ et al., 2016; LARANJO-GONZÁLEZ et al., 2017; TREVISAN et al., 2018), Americas (BRAAE et al., 2018), Africa (DERMAUW et al., 2018; HENDRICKX et al., 2019; SARATSIS

Table 1 - Number of animals inspected, cases of BCC, BCC controls, prevalence (with 95% confidence interval), OR (with 95% confidence interval), and the p-value of the ten mesoregions of Espírito Santo, Brazil, from January 2017 to December 2019.

Regional	Number of animals	BCC cases	BCC controls	Prevalence	C.I. 95% Prevalence	OR	C.I. 95% OR	p
Metropolitana	15782	315	15467	2.00	1.79--2.23	9.19	7.89--10.70	0.000000
Litoral Sul	12341	209	12132	1.69	1.48--1.94	7.77	6.54--9.23	0.000000
Caparaó	25629	416	25213	1.62	1.48--1.79	7.44	6.46--8.58	0.000000
Central Sul	28610	449	28161	1.57	1.43--1.72	7.19	6.25--8.27	0.000000
Central Serrana	6626	58	6568	0.88	0.68--1.13	3.98	3.01--5.26	0.000000
Sudoeste Serrana	5300	35	5265	0.66	0.48--0.92	3	2.12--4.25	0.000000
Noroeste	66168	256	65912	0.39	0.34--0.44	1.75	1.49--2.06	0.000000
Centro-Oeste	24009	84	23925	0.35	0.28--0.43	1.58	1.25--2.01	0.000018
Rio Doce	63019	154	62865	0.24	0.21--0.29	1.11	0.91--1.34	0.324706
Nordeste	160045	354	159691	0.22	0.20--0.25	1		
Total	407529	2330	405199	0.57	0.55--0.60			

Table 2 - Economic losses for a group of farms due to a set of 2,230 animals infected with BCC and the monetary discount usually applied in Brazil.

	Discount*	Amount discounted per carcass (US$)	Frequency (%) of destination*	Number of Carcass (n)	Total discounted amount (US$)
Liberation	0	0	65.48	1,526	0
Frezing or Salting treatment	20	92.61	25.41	592	54,825.12
Heat treatment	100	463.09	8.74	204	94,470.36
Rendering	100	463.09	0,37	8	3,704.72
Total			100%	2,330	153,000.20

*The monetary discount (%) used by slaughterhouses and the frequency (%) of each destination of the infected carcass were obtained from HENCKEL et al. (2020)

et al. 2019), and Asia (TORGERSON et al., 2019; EICHENBERGER et al., 2020) – as well as other countries – such as Russia (BOBIĆ et al., 2018) and Ethiopia (JORGA et al., 2020), plus Brazil (ROSSI et al., 2020). In the Brazilian one, the BCC prevalence described in 42 studies ranged from 0.01% in the state of Rondônia (ALVES et al., 2017) to 18.75% in indigenous villages in the state of Mato Grosso do Sul (ARAGÃO et al., 2010). In Southeastern Brazil, where the state of Espírito Santo is located, the prevalence is considered the second highest one (2.7%) (ROSSI et al., 2020), probably due to the high prevalence observed in the other states of this region, such as São Paulo (1.41%) (COMIN et al., 2021) and Minas Gerais (4.1 – 4.7%) (GARRO et al., 2015; MAGALHÃES et al., 2017). It is important to emphasize the low sensitivity of *post mortem* infection to detect BCC cases that can contribute to underestimating its occurrence (JANSEN et al., 2017; GUIMARÃES-PEIXOTO et al., 2018).

There are three previous studies including BCC epidemiology in the state of Espírito Santo (FALÇONI et al., 2013; AVELAR et al., 2016; ROSSI et al., 2017). The prevalence in the official records of this state during 2009 to 2012 established a prevalence of 0.84% with a higher occurrence during the rainy season (FALÇONI et al., 2013). Additionally, from 2010 to 2015, the prevalence was 0.51% (C.I. 95% 0.51 – 0.54%) with a stable trend during the period (ROSSI et al., 2017). These values are similar to the ones established in this study (0.57%), highlighting that *T. saginata* control remains required through adequate prophylactic strategies. Its control must be implemented across the state due to its widespread but mainly in areas considered as high-risk.

According to AVELAR et al. (2016), the counties of Ecoporanga, Linhares, Nova Venécia, Presidente Kennedy, São Mateus, Itapemirim, Mucurici, Colatina, and Barra de São Francisco are high-risk areas, based on a mathematical model that considers the variables inadequate sewage, bovine population, use and occupation of the land, and flood risks. However, these counties did not present high BCC prevalence in our study (data not shown). The region with the highest prevalence was considered the Metropolitan one composed of the municipalities Cariacica (2.20%; C.I. 95% 1.65 – 2.93%), Fundão (0.19%; 0.07 – 0.57%), Guarapari (1.92%; 1.50 – 2.46%), Serra (1.22%; 0.86 – 1.73%), Viana (2.59%; 2.22 – 3.03%), and Vila Velha (3.90%; 2.61 – 5.78%). This region is the most populated in the state, about half of the humans in the state living in such a region.

The analysis of data on risk factors required that the continuous data were transformed into categorical variables, with some potential introduction of bias (THRUSFIELD and CRHISTLEY, 2018). The high human population density contributed to a significantly higher risk) because bovine gets infected with BCC upon ingestion of *T. saginata* eggs released by the definitive hosts (human beings) in the environment, which are able to survive for long periods under different conditions (BUCUR et al., 2019). The close relation between BCC prevalence and human density had already been reported in other Brazilian states, such as Mato Grosso do Sul (PEREIRA et al., 2017) and Mato Grosso (ROSSI et al., 2016).

Thus, in these areas, it is extremely important that beef farms adopt Good Agricultural Practices to prevent BCC infection (ROSSI et al., 2015). Several risk factors for BCC occurrence have been described in Brazil such as the cattle's access to uncontrolled water sources (ROSSI et al., 2015), animal purchasing, presence of flooded pastures

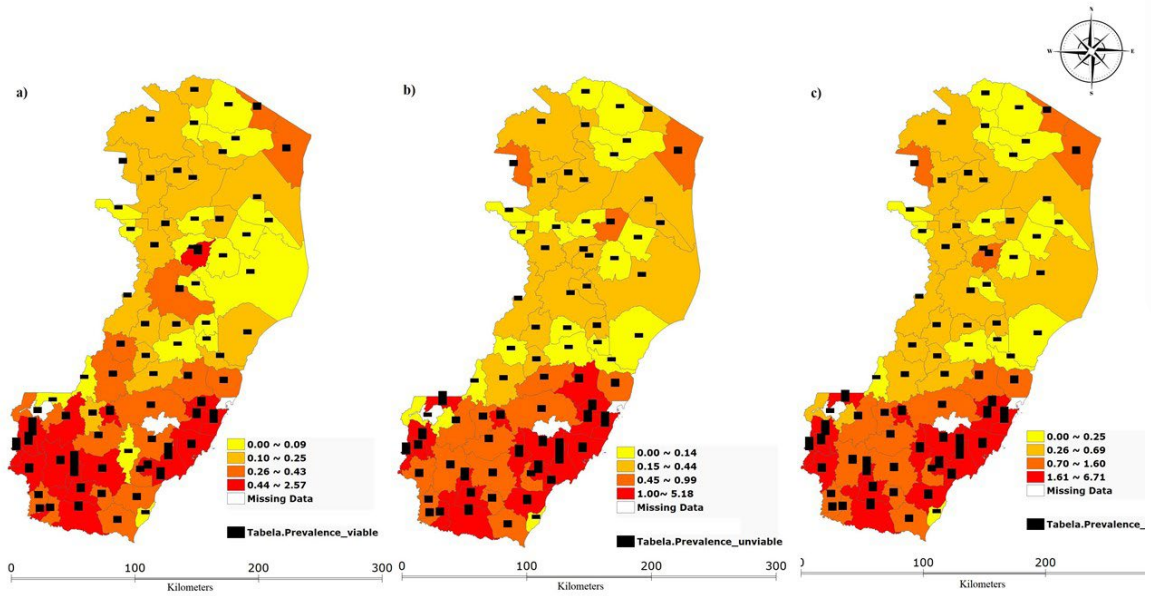

Figure 2 - Spatial distribution of BCC (a- viable, b-unviable, and c-total cysticercus) in 75 municipalities of the state of Espírito Santo, Brazil, from 2017 to 2019. The division is based on quartiles and the black bar is proportional to the prevalence.

(MAIA et al., 2017), inadequate sewage system (ALVES et al., 2017), dairy herds (COMIN et al., 2021), high rainfall index (PEREIRA et al., 2017), expertise of those responsible for farms, and the family income of farmers (DUARTE et al., 2016). In other countries, BCC occurrence is increased by location of farms, the number of slaughtered cattle, the flooding of pastures, free access of cattle to surface water, proximity to wastewater effluent (BOONE et al., 2007), presence of a railway line or a car park close to areas grazed by cattle, leisure activities around these areas, use of purchased roughage and organized public activities on farms (FLUTSCH et al., 2008), grazing, shared machinery or hired contractors, permission for animals to access risky water sources with sewage treatment plant effluent in proximity (CALVO-ARTAVIA et al., 2012), female gender, age at slaughter (CALVO- ARTAVIA et al., 2013), deworming history of household members and the distance (>2 km) of grazing fields from the homestead (ASAAVA et al., 2009), farms situated close to a permanent potential source of human fecal contamination, and those which used manure from animals other than cattle (MARSHALL et al., 2016). These factors must be controlled, if possible, during GAP adoption to avoid BCC in cattle farms.

BCC is an important cause of economic loss for beef supply chain and its control is urged. A set of 2,230 infected animals resulted in an economic loss of at least US$153,000.20 for beef producers. A possible bias of this study is the frequency of each intensity of BCC infection be different from the values reported by HENCKEL et al. (2020) which were used in our study for the evaluation of BCC economic impact. Recently, The Brazilian meat inspection law was altered due to the publication of Decree N° 10,468 in 2020 (BRAZIL, 2020), while this research was ongoing, and despite what was previously preconized, carcasses infected with a single unviable cysticercus are now obliged to be cold or heat-treated instead of having the cysticerci removed and carcass deliberately untreated. Consequently, a higher number of cattle carcasses will be financially discounted and the economic losses for farmers will be even higher. This economic loss for farmers is also important in other Brazilian areas, such as in the state of Rio Grande do Sul, where HENCKEL et al. (2020) established an economic loss of US$ 167,868.53 for

cattle suppliers of a single abattoir, and the state of São Paulo, where COMIN et al. (2021) found a loss of US$ 5,829,103.99 for farmers located in this area. These values considered only the economic loss for farmers and certainly the total economic loss is higher due to the costs of non-exporting infected carcasses, beef inspection, deboning, and taeniosis in humans as described in Belgium (JANSEN et al., 2018).

The control of BCC in Brazil requires several useful strategies based on the *One Health* concept, such as improving sewage systems treatment, avoiding flooding and illegal use of sewage on pastures, providing potable water for animals, good culinary practices, basic sanitation, health education, communication between animal and human health agencies to take actions together, anthelmintic treatment of taeniosis, combating of illegal slaughter, and improvements on beef inspection and diagnosis methodologies (ROSSI et al., 2020).

CONCLUSION

BCC prevalence in Espírito Santo state was 0.57% (C.I. 95% 0.55 – 0.60%) using meat inspection official data and some areas presented a higher risk its occurrence, which are associated with high human density. BCC detection in slaughterhouses resulted in an economic loss of at least US$153,000.20 for beef producers and our data suggest that BCC in this state is not being properly controlled over time and the adoption of prophylactic strategies to reduce its negative impact on the economy and public health remains required.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

Conceptualization: GAMR, FLT, CMF and FRB. Data acquisition: SAS, FBR, JACL and DFA. Design of methodology and data analysis: GAMR, LAM, FLT, CMF, FRA. GAMR, SAS, FBR, JACL, DFA and FRB prepared the draft of the manuscript. All authors critically revised the manuscript and approved the final version.

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